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Effect of some Soil Amendments on Fruit and Seed Yield of Sweet Pepper under Water Stress Conditions:
A. Vegetative Growth Characteristics and Chemical Constituents.

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ABSTRACT

This study was carried out at private farm, Dakahlia Governorate, Egypt, to investigate the response of deficit irrigation water under both traditional and drip irrigation systems combined with soil amendments, on the growth and chemical constituents of pepper plants (*Capsicum annum* L. "California Wonder"). The experiment tested 30 treatments arranged in strip split plot design. The horizontal-plots were allocated to the irrigation systems (surface and drip irrigation), whereas the vertical-plots were devoted to the irrigation regimes of 40, 60 and 80% from the irrigation water requirement (IWR), while the subplots were included five soil amendments (without, 250, 500 kg.fed^{-1} potassium silicate ore, and 35 and 70 kg.fed^{-1} potassium humate). The results of both seasons indicated that, drip irrigation system produced significantly higher values of vegetative growth characteristics and chemical constituents than surface irrigation system. The irrigation regime treatment at 80% following irrigation at 60 from IWR were recorded significantly highest values. The results also showed that, the higher average values were obtained from soil amendments at 70 kg/fed from potassium humate following with 500 kg/fed from potassium silicate. In addition, the results indicated that the higher average values of vegetative growth and chemical constituents were obtained from soil amendments at 70 kg/fed. from potassium humate following with 500 kg/fed. from potassium silicate under drip irrigation system at 80% from IWR following irrigation at 60% from IWR. Therefore, we recommend this treatment because it saves irrigation water and obtains the best vegetative growth and chemical constituents traits of sweet pepper plants.

Keywords: irrigation system, irrigation regime, water stress, deficit irrigation, soil amendments.

INTRODUCTION

The sweet pepper (*Capsicum annum* L.) is one of the most important vegetable crops worldwide and it has important economic value. Worldwide, the total land area of pepper cultivation in 2017 was approximately 2 million hectares, leading to the production of approximately 36 million tons (FAO Stat 2018). In Egypt, it covers a production area of old lands 43702 feddans that yielded 411116 tons and production area in new lands (Ismailia, New Valley, North Sinai and Nubaria) 48625 feddans that yielded 459027 tons, according to Ministry of Agriculture Statistics in 2018-2019.

In recent years, water scarcity is one of the limiting factors in arid and semi-arid zone. Water in Egypt was considered an important economic source because 80% of the water used was related to agriculture. Egypt has suffered from severe water shortages. Uneven distribution of water, misuse of water resources and inefficient irrigation techniques are some of the major factors in the country's water safety. Water deficit stress can cause harmful impacts on plant growth, physiological and biochemical activities, such as photosynthesis, synthesis of essential organic compounds in plant metabolism, plant-water relations and antioxidant defense ability (Ashraf and Harris, 2013). In this respect, Irrigation system plays an essential role in agriculture and the increment in the irrigated regions and scanty water resources have promoted the use of adequate irrigation systems and effective management systems that improve water-use efficiency. Therefore, maximizing water productivity and minimizing water loss have been one of the major challenges in agriculture (Jesus *et al.*, 2017).

Surface irrigation is the conventional method widely used to irrigate most of the vegetable crops grown in Egypt. However, this method uses more water compared to other high-tech water-saving irrigation method such as drip etc. Drip irrigation will open up considerable prospects to develop high value crops. Proper timing of irrigation water applications is, therefore an important decision tool to meet the water needs of the crop, to prevent yield loss due to water stress, and for maximizing the irrigation water use efficiency that resulted in beneficial use and conservation of the scarce water resources and minimize the leaching potential of nitrates (Valipour, 2015). In addition, drip irrigation can be more useful than surface irrigation. Drip irrigation system exhibited the highest values of vegetative growth; number of plants, number of branches/ plant, number of leaves/plant and WUE during studied seasons (Walters and Jha, 2016 on chili pepper and Darwish *et al.*, 2021 on some snap bean cultivars).

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Also, the soil amendments (potassium humate or silicate) will open up considerable prospects and other important decision tool to meet the water needs of the crop that improve water-use efficiency to prevent yield loss due to water stress. Humate have long been used as a soil conditioner; fertilizer and soil supplement, humic acid can be used as growth regulate-hormone improve plant growth and enhance stress tolerance (Albayrak and Camas, 2005). In addition, Potassium silicate ore A chemical compound extracted from feldspar ore, similar in its use to bentonite and zeolite, except that it differs in the absence of Al, but it contains K, Si and low amount of Fe, Zn and Mg, and it helps in holding water. Zeolites can lead to higher water-holding capacities; the treated soil capacity with natural zeolite in holding water in drought and general conditions increased 0.4-1.8 and 5-15%, respectively, compared to non-treated soil (Xiubin and Zhanbin, 2001).Silicon (Si) is element limits the effects of abiotic and biotic stresses in plants. Many researchers proved the important of silicon in resistance to osmotic pressure (Etesami and Jeong, 2018). Rarely studies of evaluation the role of Humic substances and Potassium silicate as soil application on sweet pepper growth and yield but in the following report will display its role in others crops. Humic substances as soil application have direct and indirect effects on plant growth (Chen and Aviad, 1990). Taha and Osman (2018) stated that the soil application of potassium humate was highly effective on improving the growth and yield of plants by alleviating the inhibitory effects of stress. In addition, Muhammad *et al.* (2020) reported that the addition of potassium humate on soil interacts with NPK minerals and resulted in incremental improvements in all studied vegetative and physiological parameters.

Therefore, the main goal of this study is to select the best effect of irrigation system and the best level of deficit irrigation water with soil amendments on the vegetative growth and chemical constituents of sweet pepper plants.

MATERIALS AND METHODS

This study was carried out at private farm located in Shirbin City, Dakahlia Governorate, Egypt, during the two consecutive seasons of 2017 and 2018. The purpose of the study is to investigate the response of three levels of deficit irrigation water under both traditional and drip irrigation systems combined with humate and silicate potassium ore as soil amendments, on the growth and chemical constituents of sweet pepper plants (*Capsicum annum* L. "California Wonder") planted in clay soil.

The experiment tested 30 treatments arranged in strip split plot design with three replicates. The horizontal-plots were allocated to the irrigation systems (surface and drip irrigation), whereas the vertical-plots were devoted to the irrigation regimes of 40, 60 and 80% of the irrigation water requirement (IWR), while the sub plots were included five soil amendments treatments (without, 250, 500 $kg.fed^{-1}$ potassium silicate ore and 35 and 70 $kg.fed^{-1}$ potassium humate).

Experimental soil analysis:

The physical properties and chemical analysis of the experimental soil were determined before transplanting according to A.O.A.C. (2000) and shown in (Table 1).

Table 1. Some physical and chemical analysis of the experimental soil.

Sand (%)	Silt (%)	Clay (%)	Texture class	O. M. g/kg	$CaCO_3$ g/kg	FC %	EC dS m^{-1}	pH	Available nutrients (mg/kg) N	P	K	Zn	Fe	Mn
22.56	33.15	44.29	Clay	1.83	1.88	33.5	0.98	7.95	48.9	5.16	215	1.66	11.72	7.33

The experimental unit area was 16.8 m^2, which contains 4 ridges with 6 m length and 0.7 m width. California Wonder seedlings were transplanted on the 15th of March in both seasons at spacing 40 cm on one side of the ridges.

The recommendation of fertilization according to the Egyptian Ministry of Agriculture for surface irrigation and drip irrigation as well as the monthly total fertilizer requirement for pepper/fed. is shown in Table (2).

The experiment treatments were arranged as follows:

Irrigation water treatments:

The Weather data of the weekly and monthly reference evapotranspiration in Dakahlia governorate, Egypt, during the two growing seasons (2017 and 2018) indicated in Table (3A). After 7 days from transplanting date, all experimental plots were divided into two vertical groups i.e. (surface and drip irrigation system), then every group was divided into three main groups which were subjected to irrigation regimes (i.e., 40, 60 and 80% of the irrigation water requirement (IWR). The irrigation water requirement was calculated according to Food and Agricultural Organization (FAO) Penman- Monteith (PM) procedure, FAO 56 (Allen *et al*., 1998 and Doorenbos and Pruitt, 1977).

Table 2. Monthly total fertilizer requirement for pepper/fed.

Month	Monthly Total Fertilizer Req. kg/fed.							
	Pepper Drip Irrigation				Pepper Surface irrigation			
	N	P	K	Micronutrients	N	P	K	Micronutrients
March	15.0	15.0	5.0	3.0	25.0	20.0	5.5	0.0
April	20.0	5.0	5.0	3.0	20.0	6.0	5.5	5.0
May	20.0	5.0	7.0	3.0	20.0	6.0	7.7	5.0
June	15.0	5.0	20.0	3.0	15.0	6.0	16.5	5.0
July	10.0	0.0	15.0	2.0	10.0	0.0	16.5	0.0
August	5.0	0.0	15.0	0.0	10.0	0.0	7.0	0.0
Seasonal	85.0	30.0	67.0	14.0	100.0	38.0	58.7	15.0

Surface irrigation system:

The surface irrigation part was flooded with water then plants were seedlings. After a month, water was added according to the irrigation regimes of 80% (8810 m^3/fed.), 60% (6608 m^3/fed.) and 40% (4405 m^3/fed.) of the irrigation water requirement (IWR) as average shown in Table (3 B) through a pipe extending from the main irrigation source to the experimental plots. The amount of water was calculated using a counter to measure the amount of water at the end of each pipe and the irrigation system was done with a closed line system.

Drip irrigation system:

The drip irrigation system with GR of 4 L/h emitters was done at the center of the soil beds. Irrigation was carried out according to irrigation regimes of 80 % (6922 m^3/fed.), 60% (5192 m^3/fed.) and 40 % (3461 m^3/fed.) of the irrigation water requirement (IWR), is shown in Table (3 C) and controlled by counter located at the beginning of the pipes to control in the amount of water.

Soil amendments:

Potassium silicate ore: A chemical compound extracted from feldspar ore, similar in its use to zeolite, except that it differs in the absence of Al, but it contains K, Si, and low amount of Fe, Zn, and Mg, and it helps in holding water. The chemical composition of potassium silicate ore is as follows: K% (11.5), Si % (55), Ca % (3.5), Fe % (7.3), Na % (2.1), S % (0.5), Mg % (2.3), Al% (6.1), Cl% (0.5) and KN.H.%. (11.2).

In addition, the chemical composition of potassium humate is as follows: pH (8.5), EC (0.04) dSm^{-1}, O.M (230) g kg^{-1}, N % (3.5), P % (Nil), K % (11), Ca % (0.5), Mg % (0.025), S% (0.5), Zn (100) mg g^{-1}, Cu (20) mg g^{-1}, Fe (2400) mg g^{-1}, and Mn (1700) mg g^{-1} .

Potassium silicate ore was applied at the rates of (250 and 500 kg.fed-1) and potassium humate was applied at the rates of (35 and 70 kg.fed^{-1}).

Potassium silicate ore or Potassium humate were applied as soil application, addition in two equal doses, the 1st before transplanting and incorporated into the soil and the 2nd after 30 days from transplanting with the beginning of the irrigation.

Sampling and collecting data:

After 75 days from transplanting, representative samples (three plants) were taken randomly from each experimental plot and the following parameters were recorded:

1. Vegetative growth parameters:

- Plant height Number of leaves /plant.
- Number of branches /plant. Fresh weight of plant.
- Dry weight of plant. Leaf area/plant (m^2): Leaf area was calculated according to the formula described by Koller (1972)
- Relative growth rate: calculate according to (Hunt, 1982) as follows:

$$\text{Relative growth rate} = \frac{\text{Log (W2)} - \text{log (W1)}}{\text{t2} - \text{t1}}$$

Where: **W1 and W2 are plant dry weights at times t1 and t2**

Table 3 A. Weather data of the weekly reference evapotranspiration (ETo) in Dakahlia governorate, Egypt during the two growing seasons of 2017 and 2018.

Months	Weekly	ETo 2017	ETo 2018
March	1	4.6	5.0
	2	6.1	7.2
	3	5.3	5.1
	4	5.4	8.5
April	1	6.9	6.5
	2	6.1	7.4
	3	7.9	8.9
	4	7.3	7.6
May	1	7.5	10.7
	2	10.5	9.5
	3	10.7	9.9
	4	9.8	11.8
June	1	10.5	9.6
	2	11.7	10.8
	3	10.6	11.5
	4	10.8	11.5
	5	10.8	10.9
July	1	11.4	11.0
	2	12.0	11.0
	3	11.1	11.2
	4	10.9	11.4
August	1	10.5	10.7
	2	10.0	10.3
	3	10.3	10.1
	4	10.2	9.6
	5	9.5	9.2
September	1	7.5	7.9
	2	7.4	7.0
	3	6.6	6.6
	4	6.1	6.5
Average		9.4	9.6

Table 3 B. Surface Irrigation requirement for pepper Monthly Means of Years 2017-2018 under the conditions of Dakahlia governorate, Egypt.

Month	2017 Monthly Total Irrigation Req. m^3/fed. 100%	80%	60%	40%	2018 Monthly Total Irrigation Req. m^3/fed. 100%	80%	60%	40%
March	591.2	473.0	354.7	236.5	668.3	534.6	401.0	267.3
April	1184.1	947.3	710.5	473.6	1268.0	1014.4	760.8	507.2
May	1972.8	1578.2	1183.7	789.1	2021.1	1616.9	1212.7	808.4
June	2003.2	1602.6	1201.9	801.3	2072.6	1658.1	1243.6	829.0
July	2021.0	1616.8	1212.6	808.4	2023.8	1619.0	1214.3	809.5
August	1915.0	1532.0	1149.0	766.0	1909.5	1527.6	1145.7	763.8
September	1191.9	953.5	715.1	476.8	1182.6	946.1	709.6	473.0
Seasonal	10879.3	8703.4	6527.6	4351.7	11146.0	8916.8	6687.6	4458.4

Surface irrigation water requirement (IWR)

2. Chemical constituents:

Plant samples after 75 days from transplanting were oven dried at 70° tell constant weight, then the following parameters were recorded:

- **Nitrogen content:** was determined according to Pregle (1945), using micro-kjeldahl.
- **Phosphorus content:** was determined calorimetrically according to Jackson (1967).
- Potassium content: was determined by the flame photometer according to Black (1965).
- **Silicon concentration:** was determined by the spectrophotometer at 820 nm according to Hogendorp *et al.* (2012).

- Total chlorophyll was calorimetrically determined according to the methods described by Goodwine (1965).

Table 3 C. Drip Irrigation requirements for pepper Monthly Means of Years 2017-2018 under the conditions of Dakahlia governorate, Egypt.

Month	Drip Irrigation water requirement (IWR)							
	2017				2018			
	Monthly Total Irrigation Req. m^3/fed.				Monthly Total Irrigation Req. m^3/fed.			
	100%	80%	60%	40%	100%	80%	60%	40%
March	464.5	371.6	278.7	185.8	525.1	420.1	315.1	210.0
April	930.4	744.3	558.2	372.2	996.3	797.0	597.8	398.5
May	1550.1	1240.1	930.1	620.0	1588.0	1270.4	952.8	635.2
June	1573.9	1259.1	944.3	629.6	1628.5	1302.8	977.1	651.4
July	1588.0	1270.4	952.8	635.2	1590.1	1272.1	954.1	636.0
August	1504.7	1203.8	902.8	601.9	1500.3	1200.2	900.2	600.1
September	936.5	749.2	561.9	374.6	929.2	743.4	557.5	371.7
Seasonal	8548.0	6838.4	5128.8	3419.2	8757.5	7006.0	5254.5	3503.0

Statistical analysis:

Data were statistically analyzed according to the technique of analysis variance (ANOVA) and Duncan's method was used to compare the difference between the means of treatment values according to the methods described by Gomez and Gomez (1984). All statistical analyses were performed using the analysis of variance technique by means of COSTATE Computer Software.

RESULTS AND DISCUSSION

1. Characteristics of Vegetative Growth:

Effect of irrigation system

Regarding to the significant effect of irrigation system (Table 4), data resulted that both irrigation systems drip irrigation and surface irrigation had a significant effect on vegetative growth parameters (plant height, number of leaves/plant, number of branches/plant, fresh weight, dry weight and leaf area). The drip irrigation revealed the highest mean values comparing with the surface irrigation during both seasons. While the relative growth rate found the opposite has been recorded, which mean that surface irrigation recorded the highest relative growth rate.

The increase in vegetative growth parameters due to drip irrigation system may be credited to the ideal availability of soil moisture as well as plant nutrients in the soil (Pattanaik *et al.* 2003 and Yasemin *et al.* 2014). While, the low vegetative growth parameters due to the surface irrigation system may be because of moisture stress made by negative moisture conditions due higher percolation losses under surface water system (Antony and Singandhupe 2003 and Vazquez *et al.* 2005). Drip water system may have provided water and supplements in sufficient extent all through the growing time of yield, which triggered the plant growth through accumulation of higher photosynthesis in the plant leaves coming about more vegetative growth Aujla *et al.* (2004) and Bhardwaj *et al.* (2018).

Similar positive results of irrigation system on vegetative growth characteristics are in accordance with those obtained by El-Saei and Tartoura (2005) on potato, Yonts (2010) on bean; Lodhi *et al.* (2014) on sweet pepper; Walters and Jha (2016) on chili pepper; Bhardwaj *et al.* (2018) on chili pepper; Abdelshafy *et al.* (2021) on potato and Darwish *et al.* (2021) on bean.

Effect of irrigation regimes

The highest significant values of vegetative growth parameters in the Table (4) as affected by the increasing of irrigation regimes (40, 60 and 80% from IWR were obtained with the highest level of irrigation regime 80% followed by irrigation regime at 60% from IWR, while the relative growth rate recorded the highest values with 40% from IWR.

Table 4. Effect of irrigation system and regime as well as soil amendments on some vegetative growth characteristics during 2017 and 2018 seasons.

Treatments	Plant height (cm)		Number of leaves/plant		Number of branches/plant		Fresh weight /plant (g)		Dry weight /plant (g)		Leaf area (m^2)		Relative growth rate	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Irrigation system														
Surface irrigation	42.32b	43.70b	12.87b	13.56b	5.69b	6.04b	178.74b	181.38b	28.41b	29.34b	3.10b	3.29b	0.0028a	0.0028a
Drip irrigation	47.39a	50.30a	14.96a	15.62a	6.33a	6.75a	183.33a	186.46a	28.86a	29.82a	3.23a	3.44a	0.0021b	0.0021b
F. test	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Irrigation regimes														
80%	50.42a	52.77a	15.63a	16.33a	6.29a	6.69a	187.57a	190.47a	31.39a	32.39a	3.32a	3.53a	0.0021c	0.0021c
60%	45.99b	48.15b	14.33b	15.03b	6.08b	6.47b	182.39b	185.78b	29.17b	30.16b	3.19b	3.39b	0.0023b	0.0023b
40%	38.16c	40.07c	11.77c	12.40c	5.65c	6.03c	173.14c	175.50c	25.35c	26.19c	2.98c	3.18c	0.0029a	0.0029a
Soil amendments (Kg/fed.)														
0	40.46e	42.40e	12.44d	13.22c	5.76c	6.13e	175.90e	178.27e	26.42e	27.32e	3.04d	3.23d	0.0028a	0.0028a
K Si 250	43.93d	46.10d	13.67c	14.39b	5.97b	6.37d	180.01d	183.17d	28.18d	29.09d	3.14c	3.35c	0.0025bc	0.0025b
K Si 500	46.61b	48.79b	14.44ab	15.06ab	6.14a	6.51b	183.11b	185.92b	29.52b	30.46b	3.21b	3.41b	0.0023cd	0.0023c
K H 35	45.31c	47.49c	14.11bc	14.72ab	6.02b	6.41c	181.47c	184.45c	28.89c	29.86c	3.18b	3.39b	0.0025b	0.0025b
K H 70	47.97a	50.22a	14.89a	15.56a	6.16a	6.56a	184.69a	187.78a	30.17a	31.17a	3.25a	3.46a	0.0023d	0.0023c

Means followed by the same letter within each column do not significantly differed using Duncan's Multiple Rang Test at the level of 5%.

The increment in vegetative growth parameters with increasing in irrigation regimes might be attributed to that irrigation water is a substantial factor in plant life. Therefore, the availability of adequate soil moisture gave good supply with sufficient and optimum irrigation water amount improved plant roots characteristics and temperature positively enhanced biochemical and physiological plant activities, increased availability, absorption and usage of essential nutrients, which in turn resulted in increased plant growth traits and vice versa in the case of insufficient irrigation water amounts which contributes and improving cellular plant growth of the plant in sweet pepper. Debbarma *et al.* (2019) studied the effects of drip irrigation regimes on sweet pepper production. Four drip irrigation regimes (100, 80, 60 and 40 % of crop water requirement) and surface irrigation. They observed that plant morphological parameters were significantly increased by drip irrigation. In this trend, some studies supported the current result as Diaz-Perez (2009); Choudhary and Bhambri (2012); El-Said (2015); Rasal *et al.* (2017); Kotb (2019); Oliveira *et al.* (2019) and Vinayak *et al.* (2019) on pepper; and on tomato as Dawa *et al.* (2019) and Shabbir *et al.* (2020).

Effect of soil amendments

The represented data in Table (4) clarified the effect of soil amendments as potassium silicate and humate at different rates on vegetative growth parameters. Data indicated that the soil amendments of both potassium silicate and humate significantly affected in vegetative growth parameters. With soil addition of 70 kg.fed^{-1} from potassium humate followed by 500 kg.fed^{-1} potassium silicate, the highest values were recorded comparing with control (without). While relative growth rate recorded the highest values with the untreated plants comparing with other treatments during both seasons. The increase in vegetative growth may be due to the positive effect of humic acid on vegetative growth because of the part of humic contains a lot of elements which improved the soil fertility then increased available of nutrients, soil organic matter and consequently increased plant growth (El-Sayed *et al.* 2019). These results are in the same line as soil application of humic acid with those of Chen and Aviad (1990); Barakat (2015) on bean; AbdEllatif *et al*. (2017) on tomato; Akladious and Mohamed (2018) on pepper; Colpas-Castillo *et al*. (2018) on chili pepper; Taha and Osman (2018) on bean; Raheem *et al*. (2018) on lettuce; Muhammad *et al.* (2020) on potato; Reyes-Pérez *et al.* (2020) on tomato; Ullah *et al.* (2020) on cotton and Dunoyer *et al.* (2022) on melon and tomato.

Concerning to the effects of potassium silicate on vegetative growth, the increase in vegetative growth of pepper plant may be due to the helpful impact used of potassium silicate ore as soil conditioners to improve soil physio-chemical properties. Potassium silicate ore like Zeolite, are used in agriculture as soil amendment to its higher ability to not only lose water, but also gain it (Mumpton and Laroca, 1999), Several positive effects on soil properties, such as increasing soil moisture, promoting hydraulic conductivity, and increasing growth and yields. It used as soil conditioners to improve soil physio-chemical properties (Kralova *et al.* 1994). On the same subject, Abd El-Basir and Swelam (2017) showed that Zeolite significantly enhanced vegetative growth parameters of sweet pepper, chemical constituents compared to the control. In addition, silicon on stimulation of good upstanding under drought stress, regulating and expanding in nutrients absorption and transportation from the roots to the shoots, which ameliorate plant metabolism and enhance the movement of assimilates required for good plant development and for good resistance against drought stress. These results are in accordance with those found by Kotb (2019) on sweet pepper but as a foliar application

Effect of interactions:

Irrigation system and irrigation regimes

Regarding the effect of interaction between systems and regimes of irrigation, data in Table (5) showed positively effective on vegetative growth parameters. In this concern, the highest values of vegetative growth were recorded when plants irrigated at 80% from IW under both of irrigation systems with significant differences between all treatments. With a significant increase found highest mean values of vegetative growth parameters recorded with 80% from IWR under the drip irrigation system followed by the same rate under the surface irrigation system. The same trend was true during both seasons. In the same Table, the results indicated that relative growth rate recorded the highest mean value at 40% from IWR under surface irrigation. These results are in accordance with those found by Pourasadollahi *et al.* (2019) and Abdelshafy *et al.* (2021) on potato.

Irrigation system and soil amendments

Regarding the effect of the interaction between irrigation systems and soil amendments (potassium silicate and humate) at different rates on vegetative growth parameters. The results in Table (6) revealed that all interactive treatments increased significantly mentioned parameters. The highest were obtained due to the drip irrigation system with soil amendments. The highest rate at 70 kg.fed^{-1} of potassium humate with drip irrigation system were recorded the highest significant vegetative growth parameters followed by application potassium humate at 500 kg.fed^{-1} during the growing seasons In the same Table, The results indicated that relative growth rate recorded the highest mean value under surface irrigation only with soil amendments. These results are in accordance with those found by Omer *et al.* (2020).

Irrigation regimes and soil amendments

Concerning the interaction effect between irrigation regimes and soil amendments with K-silicate or humate at different rates comparing to the control, data in Table (7) showed that significant effects on the vegetative growth traits during 2017and 2018 seasons. In the same Table, the results showed with soil addition with any forms increased mentioned parameters. The highest values of vegetative parameters were recorded with 70 kg.fed^{-1} potassium humate followed by addition potassium silicate at 500 kg.fed^{-1} significant increase under 80% from IWR. The same trend was true in both seasons. In the same Table data indicated that the relative growth rate recorded the highest mean value at 40% from IWR in the control (without soil addition).

In general, rarely studies of evaluation the role of soil amendments as potassium humate or potassium silicate with irrigation regime on sweet pepper growth. Such researches were accordant with successful interaction between irrigation regimes and soil amendments with K-silicate or humate as Kotb *et al*. (2018), Youssif *et al.* (2018), Yıldıztekin *et al*. (2018), El-Sayed *et al.* (2019), Kotb (2019), Mahmoud *et al.* (2019), Abd Allah *et al.* (2021), Al-Issawi *et al.* (2021) and AL-Shamary *et al.* (2021).

Table 5. Effect of double interaction between irrigation system X regime on some vegetative growth characteristics during 2017 and 2018 seasons.

Treatments		Plant height (cm)		Number of leaves/plant		Number of branches/plant		Fresh weight /plant (g)		Dry weight /plant (g)		Leaf area (m²)		Relative growth rate	
		2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Surface irrigation	80%	47.79c	49.39c	14.40c	15.13b	5.98c	6.33d	185.30b	188.22b	30.75b	31.78b	3.23c	3.42c	0.0023d	0.0023d
	60%	43.48d	44.85d	13.27d	14.00c	5.76d	6.11e	180.06c	182.61c	28.86d	29.78d	3.12d	3.31d	0.0027b	0.0026b
	40%	35.69f	36.86f	10.93f	11.53d	5.34e	5.69f	170.87e	173.30e	25.62e	26.47e	2.94f	3.13f	0.0034a	0.0034a
Drip irrigation	80%	53.04a	56.16a	16.87a	17.53a	6.60a	7.04a	189.85a	192.73a	32.04a	33.00a	3.40a	3.63a	0.0020e	0.0019f
	60%	48.51b	51.46b	15.40b	16.07b	6.41b	6.84b	184.73b	188.94b	29.49c	30.54c	3.26b	3.48b	0.0020e	0.0021e
	40%	40.63e	43.28e	12.60e	13.27c	5.97c	6.37c	175.41d	177.70d	25.07f	25.90f	3.02e	3.22e	0.0024c	0.0025c

Means followed by the same letter within each column do not significantly differed using Duncan's Multiple Rang Test at the level of 5%

Table 6. Effect of double interaction between irrigation system X soil amendments on some vegetative growth characteristics during 2017 and 2018 seasons.

Treatments		Plant height (cm)		Number of leaves/plant		Number of branches/plant		Fresh weight /plant (g)		Dry weight/ plant (g)		Leaf area (m²)		Relative growth rate	
		2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Surface irrigation	0	38.16i	39.48i	11.67g	12.56d	5.45g	5.78h	173.50g	176.10h	26.50h	27.42h	2.99f	3.17g	0.0032a	0.0032a
	K Si 250	41.37h	42.63h	12.56f	13.33cd	5.67f	6.04g	177.79f	180.51g	28.04g	28.90g	3.08e	3.28f	0.0029b	0.0028b
	K Si 500	44.01f	45.47f	13.33de	13.89cd	5.78e	6.12f	180.79de	183.52e	29.15d	30.11d	3.14d	3.33e	0.0026cd	0.0027c
	K H35	42.75g	44.21g	13.00ef	13.56cd	5.71ef	6.06g	179.26ef	181.79f	28.60e	29.58e	3.10e	3.30f	0.0028bc	0.0028b
	K H70	45.30e	46.70e	13.78d	14.44bc	5.85d	6.22e	182.38cd	184.98d	29.74c	30.70c	3.17d	3.36d	0.0025de	0.0025d
Drip irrigation	0	42.77g	45.32f	13.22d-f	13.89cd	6.07c	6.47d	178.30f	180.43g	26.34i	27.21i	3.08e	3.29f	0.0024e	0.0024e
	K Si 250	46.49d	49.57d	14.78c	15.44ab	6.27b	6.69c	182.23cd	185.83d	28.32f	29.28f	3.20c	3.41c	0.0020f	0.0021fg
	K Si 500	49.21b	52.11b	15.56ab	16.22a	6.49a	6.91a	185.44ab	188.33b	29.90b	30.80b	3.28b	3.49b	0.0021f	0.0020g
	K H35	47.86c	50.77c	15.22bc	15.89a	6.34b	6.76b	183.68bc	187.11c	29.17d	30.14d	3.25b	3.47b	0.0022f	0.0021f
	K H70	50.64a	53.74a	16.00a	16.67a	6.46a	6.91a	187.00a	190.58a	30.59a	31.64a	3.32a	3.55a	0.0020f	0.0021f

Means followed by the same letter within each column do not significantly differed using Duncan's Multiple Rang Test at the level of 5%.

Table 7. Effect of double interaction between irrigation regimes X soil amendments on some vegetative growth characteristics during 2017 and 2018 seasons.

Treatments		Plant height (cm)		Number of leaves/plant		Number of branches/plant		Fresh weight /plant (g)		Dry weight/ plant (g)		Leaf area (m²)		Relative growth rate	
		2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
80%	0	43.65i	45.66i	13.50gh	14.33e-h	5.92f	6.29h	179.58fg	182.02f	28.01i	28.96i	3.12g	3.32g	0.0026de	0.0026d
	K Si 250	50.12d	52.63d	15.50b-d	16.33a-d	6.29cd	6.71c	187.30bc	189.97d	31.20d	32.19d	3.31c	3.54c	0.0021gh	0.0021g
	K Si 500	52.76b	55.14b	16.33ab	17.00ab	6.41ab	6.77b	190.09ab	193.49b	32.56b	33.57b	3.39ab	3.58b	0.0020h	0.0020hi
	K H35	51.56c	53.96c	16.00a-c	16.5a-c	6.35bc	6.75b	189.05ab	191.65c	31.94c	33.00c	3.35b	3.56b	0.0020gh	0.0020gh
	K H70	54.00a	56.49a	16.83a	17.50a	6.48a	6.92a	191.86a	195.24a	33.25a	34.25a	3.41a	3.64a	0.0019h	0.0020i
60%	0	42.36j	44.24j	13.17gh	14.00f-i	5.85fg	6.22i	178.09gh	180.51g	27.29j	28.20j	3.09h	3.28h	0.0026de	0.0026d
	K Si 250	44.96h	47.14h	14.00fg	14.67d-g	6.02e	6.41g	181.28ef	185.95e	28.69h	29.70h	3.16f	3.37f	0.0022fg	0.0022f
	K Si 500	47.59f	49.85f	14.83d-f	15.50b-f	6.28cd	6.66d	184.51cd	187.23e	29.94f	30.91f	3.23e	3.43e	0.0022fg	0.0022f
	K H35	46.16g	48.44g	14.50ef	15.17c-f	6.08e	6.49f	182.44de	186.51e	29.33g	30.34g	3.20e	3.42e	0.0024ef	0.0024e
	K H70	48.91e	51.09e	15.17c-e	15.83a-e	6.20d	6.59e	185.65c	188.69d	30.61e	31.64e	3.27d	3.47d	0.0022fg	0.0023ef
40%	0	35.38o	37.29o	10.67k	11.33k	5.52k	5.88m	170.02 l	172.27k	23.98o	24.78o	2.91j	3.10m	0.0032a	0.0032a
	K Si 250	36.72n	38.54n	11.50jk	12.17jk	5.61j	5.99l	171.45kl	173.57j	24.65n	25.39n	2.94j	3.14l	0.0030ab	0.0030b
	K Si 500	39.48l	41.38l	12.17ij	12.67h-k	5.72hi	6.10k	174.74ij	177.06h	26.07 l	26.89l	3.01i	3.22j	0.0028bc	0.0028c
	K H35	38.21m	40.07m	11.83ij	12.50i-k	5.64ij	6.00l	172.93jk	175.19i	25.39m	26.25m	2.98i	3.18k	0.0030ab	0.0030b
	K H70	41.01k	43.08k	12.67hi	13.33g-j	5.79gh	6.18j	176.56hi	179.41g	26.64k	27.62k	3.05h	3.26i	0.0027cd	0.0027c

Means followed by the same letter within each column do not significantly differed using Duncan's Multiple Rang Test at the level of 5%

Irrigation system, irrigation regimes and soil amendments

Data in Table (8) presented the effect of interaction among all studied factors on all tested traits. The results showed that the soil application with potassium humate at the rate of 70 $kg.fed^{-1}$ followed by potassium silicate at 500 $kg.fed^{-1}$under irrigation regime at 80% from IWR under drip irrigation recorded the highest mean values of vegetative growth parameters. The relative growth rate recorded the highest values under surface irrigation with irrigation regimes at 40% from IWR and without soil amendments. The same trend was true during both seasons. These results may be attributed to the effective roles of soil amendments as potassium humate or potassium silicate with drip irrigation system and irrigation regime. This treatment increasing water uptake and improving essential elements absorption and availing them in the different plant physiological and biochemical processes such as photosynthesis etc. and production of various assimilates and solutes that are important to form good new plant organs and consequently improvement vegetative growth traits. Also, the role of increasing irrigation regimes to at 80% from IWR under drip irrigation which, delivers water and nutrients at a small rate, according to the requirements of the plants at frequent intervals in the crop root zone, which increases the availability of nutrients compared to the conventional method of irrigation. More nutrient availability, especially near the root zone might have increased the translocation of photosynthesis to the storage organ of sweet pepper resulting in an increased weight of sweet pepper plants.

Table 8. Effect of triple interaction among irrigation system X irrigation regime X soil amendments on some vegetative growth characteristics during 2017 and 2018 seasons.

Treatments			Plant height (cm)		Number of leaves/plant		Number of branches/plant		Fresh weight / Plant (g)		Dry weight/ plant (g)		Leaf area (m^2)		Relative growth rate	
			2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Surface irrigation	80%	0	41.35no	42.86r	12.67k-m	13.67f-k	5.60no	5.90r	177.25j-l	180.14lm	27.85o	28.86p	3.07no	3.24m	0.0029de	0.0029e
		K Si 250	47.49i	49.12j	14.00g-j	15.00c-g	5.98ij	6.36n	184.97e-g	187.92g	30.65g	31.71h	3.22hi	3.43gh	0.0023i-l	0.0024ij
		K Si 500	50.04g	51.77h	15.00e-g	15.67b-f	6.10g-i	6.42l	187.67c-e	190.90d-f	31.76e	32.83e	3.29fg	3.47f	0.0021k-n	0.0022kl
		K H35	48.91h	50.53i	14.67f-h	15.00c-g	6.04hi	6.41lm	187.02d-f	189.96ef	31.13f	32.18g	3.25gh	3.45fg	0.0021j-n	0.0022kl
		K H70	51.14ef	52.65g	15.67df	16.33a-e	6.18fg	6.56ij	189.57b-d	192.17cd	32.35d	33.33d	3.31ef	3.51e	0.0020l-n	0.0020mn
	60%	0	40.09pq	41.35t	12.33l-n	13.33f-k	5.54op	5.85s	175.64k-m	178.14no	27.24p	28.10r	3.02o-q	3.19n	0.0029de	0.0029ef
		K Si 250	42.50m	43.77q	13.00j-l	13.67f-k	5.71mn	6.09q	178.94i-k	181.96kl	28.44m	29.32n	3.10mn	3.30l	0.0028d-f	0.0027g
		K Si 500	44.91k	46.39n	13.67h-k	14.33d-i	5.84kl	6.19p	182.15g-i	184.65hi	29.44k	30.39l	3.15j-l	3.35jk	0.0024g-j	0.0024ij
		K H35	43.61l	45.10o	13.33i-l	14.00e-j	5.78lm	6.16p	180.21h-j	182.63jk	29.03l	30.04m	3.13k-m	3.33kl	0.0027e-g	0.0027fg
		K H70	46.27j	47.61l	14.00g-j	14.67c-h	5.90j-l	6.26o	183.36f-h	185.68h	30.13i	31.05j	3.19ij	3.38i	0.0024g-j	0.0024ij
	40%	0	33.04w	34.22z	10.00p	10.67l	5.22s	5.59v	167.61p	170.01t	24.42w	25.30y	2.88s	3.08q	0.0037a	0.0038a
		K Si 250	34.13v	35.00y	10.67op	11.33kl	5.31rs	5.68u	169.46op	171.63st	25.04v	25.68x	2.91s	3.12p	0.0036ab	0.0035b
		K Si 500	37.09t	38.25w	11.33no	11.67j-l	5.39qr	5.73t	172.55m-o	175.01q	26.25s	27.11u	2.97qr	3.16o	0.0033bc	0.0033c
		K H35	35.73u	36.99x	11.00op	11.67j-l	5.30rs	5.62v	170.57n-p	172.80rs	25.66u	26.52w	2.93rs	3.11p	0.0035ab	0.0035b
		K H70	38.48rs	39.85v	11.67m-o	12.33h-l	5.47pq	5.82s	174.20l-n	177.08op	26.74q	27.72s	3.00pq	3.19no	0.0031cd	0.0031d
Drip irrigation	80%	0	45.95j	48.45k	14.33g-i	15.00g-l	6.24ef	6.68h	181.91g-i	183.90h-j	28.16n	29.06o	3.17i-k	3.40hi	0.0023i-m	0.0022kl
		K Si 250	52.74d	56.13d	17.00a-c	17.67ab	6.59bc	7.05d	189.62b-d	192.03cd	31.75e	32.67f	3.40cd	3.64c	0.0019no	0.0018pq
		K Si 500	55.48b	58.51b	17.67a	18.33a	6.72a	7.11bc	192.51ab	196.08b	33.36b	34.32b	3.48ab	3.68b	0.0018no	0.0017q
		K H35	54.20c	57.39c	17.33ab	18.00ab	6.66ab	7.09c	191.07a-c	193.34c	32.76c	33.82c	3.45bc	3.67bc	0.0019no	0.0019n-p
		K H70	56.85a	60.33a	18.00a	18.67a	6.78a	7.27a	194.14a	198.31a	34.15a	35.16a	3.52a	3.77a	0.0019no	0.0019o-q
	60%	0	44.63k	47.13m	14.00g-j	14.67c-h	6.16f-h	6.58i	180.54h-j	182.87i-k	27.33p	28.30q	3.15j-m	3.37ij	0.0023i-l	0.0023jk
		K Si 250	47.42i	50.51i	15.00e-g	15.67c-h	6.32de	6.74g	183.61f-h	189.94ef	28.94l	30.08m	3.22hi	3.43g	0.0017o	0.0018pq
		K Si 500	50.28fg	53.30f	16.00c-e	16.67b-f	6.72a	7.14b	186.87d-f	189.80f	30.44h	31.42i	3.31ef	3.52e	0.0020k-n	0.0021lm
		K H35	48.70h	51.78h	15.67d-f	16.33a-d	6.37d	6.82f	184.68e-g	190.40d-f	29.62j	30.65k	3.28fg	3.51e	0.0020k-n	0.0020m-o
		K H70	51.54e	54.57e	16.33b-d	17.00abc	6.50v	6.92e	187.94c-e	191.70c-e	31.09f	32.24g	3.35de	3.56d	0.0020m-o	0.0022kl
	40%	0	37.72st	40.37u	11.33no	12.00i-k	5.81k-m	6.16p	172.44m-o	174.54qr	23.54x	24.26yz	2.93rs	3.11pq	0.0026e-h	0.0025hi
		K Si 250	39.31qr	42.07s	12.33l-n	13.00g-l	5.91jk	6.29o	173.44l-o	175.51pq	24.26w	25.09z	2.97qr	3.16o	0.0025f-i	0.0026gh
		K Si 500	41.87mn	44.51q	13.00j-l	13.67f-k	6.04hi	6.47k	176.93j-l	179.11mn	25.89t	26.67v	3.06no	3.27m	0.0023h-k	0.0023jk
		K H35	40.69op	43.14r	12.67k-m	13.33f-k	5.98ij	6.38mn	175.28k-m	177.58no	25.12v	25.97x	3.03op	3.24m	0.0025f-i	0.0025hi
		K H70	43.55l	46.31n	13.67h-k	14.33d-i	6.10g-i	6.53j	178.93i-k	181.74kl	26.54r	27.52t	3.11lmn	3.33kl	0.0023i-l	0.0023jk

Means followed by the same letter within each column do not significantly differed using Duncan's Multiple Rang Test at the level of 5%.

2. Chemical Constituents of Plants:

Effect of irrigation system

The obtained results in Table (9) indicated that both irrigation systems (surface and drip) significantly affected on chemical constituents (N, P, K and Si% and total chlorophyll content) of sweet pepper plants. It could be noticed, that drip irrigation was the most effective on chemical constituents comparing with the surface one. The same trend was true during both seasons. The enhancement due to the drip irrigation may be referred to the effectiveness the irrigation system in supplying nutrient in small quantities according to the requirements of the plants at frequent intervals in the crop root zone, which increases the availability of nutrients compared to the conventional method of irrigation. These results are in good accordance with those reported by Amer *et al*. (2016) and Abdelshafy *et al*. (2021) on Potato.

Effect of irrigation regimes

Concerning the main effect of irrigation water regimes (40, 60 and 80% from AIW), data in Table (9), indicated that the chemical constituents were increased significantly with increasing irrigation regimes from 40% to 80% from IWR. The highest mean values recorded with the highest level of irrigation at 80% following irrigation at 60% from IWR, while the lowest one recorded with irrigation at 40% AIW during both seasons of 2017 and 2018. The increase in nutrient concentration with the increasing in irrigation values perhaps refer to increasing in amount of available water in plant growing media around the root zone with good soil drainage and multiple roots, so the plant could uptake sufficient quantities of the requirement from different soluble elements as N, P, K and Si needed to a lot of plant metabolic activities and consequently the growth plant leaf tissue contains several amounts of these components.

These findings are consistent with Erdem *et al.* (2006) on potato; Albuquerque *et al.* (2012); El-Said (2015); Patil and Das (2015); Kumar *et al*. (2016); Kuscu *et al.* (2016); Dhotre *et al.* (2018) on pepper and Dawa *et al.* (2019) and Shabbir *et al.* (2020) on tomato.

Effect of soil amendments

As shown in Table (9) soil application of both potassium silicate and humate significantly affected in the of chemical constituents content of sweet pepper plants during both seasons. The highest values were recorded with soil addition of 70 kg.fed^{-1} from potassium humate followed by 500 kg.fed^{-1} potassium silicate during both seasons of the experiments. While the highest mean value of Si% was recorded with the addition of 500 kg.fed^{-1} potassium silicate comparing the control.

The increase in chemical constituents content due to humic acid significantly diminished soil pH and EC and increased exchangeable K, Ca, Na and Mg (Mindari *et al.*, 2014), therefore improving chemical analysis of sweet pepper plants. Asri *et al*. (2015) showed that N, P, K, Ca, Zn and Mn concentration of tomato plants were increased by humic acid. Similar results were stated by Aminifard *et al*. (2012) on pepper; Khan *et al*. (2013) on pepper; Barakat (2015) on bean; AbdEllatif *et al*. (2017) on tomato; Kumar *et al*. (2017); Akladious and Mohamed (2018) on pepper and Taha and Osman (2018 on bean.

Table 9. Effect of irrigation system and regime as well as soil amendments on chemical constituents of plants during 2017 and 2018 seasons.

Treatments	N %		P %		K %		Si %		Total chlorophyll mg g^{-1} FW	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Irrigation system										
Surface irrigation	2.69b	3.04b	0.421b	0.444b	3.04b	3.28b	0.26b	0.34b	1.242b	1.265b
Drip irrigation	2.95a	3.23a	0.434a	0.469a	3.23a	3.57a	0.29a	0.44a	1.329a	1.377a
F. test	**	**	**	**	**	**	**	**	**	**
Irrigation regimes										
80%	3.12a	3.41a	0.498a	0.522a	3.44a	3.70a	0.33a	0.48a	1.360a	1.395a
60%	2.88b	3.19b	0.442b	0.469b	3.21b	3.48b	0.31b	0.44b	1.305b	1.343b
40%	2.46c	2.80c	0.344c	0.377c	2.77c	3.09c	0.18c	0.25c	1.193c	1.225c
F. test	**	**	**	**	**	**	**	**	**	**
Soil amendments (Kg/fed.)										
0	2.57e	2.92e	0.373e	0.404e	2.89e	3.21e	0.22e	0.29e	1.226e	1.259e
K Si 250	2.76d	3.09d	0.417d	0.445d	3.09d	3.38d	0.31b	0.45b	1.275d	1.312d
K Si 500	2.92b	3.23b	0.449b	0.477b	3.24b	3.51b	0.33a	0.47a	1.310b	1.345b
K H35	2.84c	3.16c	0.434c	0.462c	3.16c	3.45c	0.25d	0.35d	1.290c	1.326c
K H70	2.99a	3.29a	0.466a	0.493a	3.30a	3.58a	0.27c	0.38c	1.328a	1.363a
F. test	**	**	**	**	**	**	**	**	**	**

Means followed by the same letter within each column do not significantly differed using Duncan's Multiple Rang Test at the level of 5%.

In addition, the increase in chemical constituents content may be due to the helpful impact used of potassium silicate as soil conditioners to improve soil physio-chemical properties. Potassium silicate like Zeolite, are used in agriculture as soil amendment to its higher ability to not only lose water, but also gain it (Mumpton and Laroca, 1999), its strong absorption properties, macro and micronutrient contents (Manolov *et al.,* 2005). On sweet pepper, Abd El-Basir and Swelam (2017) showed that Zeolite significantly enhanced chemical constituents and fruit quality compared to the control. In addition, silicon on stimulation of good expanding in nutrients absorption and transportation from the roots to the shoots. These results are in accordance with those found by Kotb (2019) on sweet pepper but as a foliar application, In this trend, Nasseem *et al*. (2011); Lobato *et al.* (2009) and Marodin *et al*. (2014).

Effect of interactions:

Irrigation system and irrigation regimes

Data in Table (10) showed that the interaction effect between irrigation system and irrigation regimes (40, 60 and 80% of IWR) on chemical constituents of plants. All treatments significantly affected on mentioned parameters. It could be observed that pepper plant irrigated at the level of 80% gave the highest mean values under both surface and drip irrigation system. It could be observed that drip irrigation was the highest followed by surface irrigation at 80% from IWR. Such effect was more pronounced for the plants irrigated under drip irrigation at 80% followed by 60% from IWR during both seasons (Abdelshafy *et al*., 2021) on potato.

Table 10. Interaction effect between irrigation system and regime on chemical constituents of plants during 2017 and 2018 seasons.

Treatments		N%		P%		K%		Si %		Total Chlorophyll mg g^{-1} FW	
		2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Surface irrigation	80%	2.98c	3.30b	0.491a	0.507b	3.35b	3.53b	0.32b	0.43c	1.313c	1.338c
	60%	2.74d	3.10c	0.436b	0.457d	3.11d	3.33d	0.29c	0.38d	1.264d	1.288d
	40%	2.34f	2.72e	0.338c	0.366f	2.66f	2.98f	0.16e	0.19f	1.150f	1.170f
Drip irrigation	80%	3.25a	3.53a	0.505a	0.538a	3.52a	3.88a	0.34a	0.53a	1.407a	1.451a
	60%	3.01b	3.29b	0.448b	0.482c	3.30c	3.63c	0.32b	0.49b	1.345b	1.398b
	40%	2.58e	2.89d	0.350c	0.387e	2.87e	3.21e	0.21d	0.30e	1.235e	1.281e

Means followed by the same letter within each column do not significantly differed using Duncan's Multiple Rang Test at the level of 5%.

Irrigation system and Soil amendments

The different comparison between the mean values of total chlorophyll content, N, P, K and Si% of plants as affected by the combination between irrigation system and soil amendments of potassium silicate and humate at different rats are presented in Table (11). Data clearly showed that; irrigation system combination with soil application has been recorded a significant stimulation effect on the average values of all the aforementioned traits. In addition, the highest mean values recorded with drip irrigation system and 70 kg.fed^{-1} followed by 500 kg.fed^{-1} potassium silicate for N, P and K%, while drip irrigation and addition of 500 kg.fed^{-1} potassium silicate was the best for the highest mean values of Si%. This trend was true during both seasons of the experiments. Similar results were stated by Omer *et al.* (2020).

Irrigation regimes and Soil amendments

Data tabulated in Table (12) indicated that the average values of chlorophyll content, N, P and K% and Si of pepper plants were significantly increased as a result of soil application with different rates of potassium silicate or humate addition with increasing irrigation regimes from 40 to 80% from IWR. All rates of potassium silicate or humate increased significantly the previous traits. The highest mean values for chlorophyll content, N, P and K% in plants mentioned were found to be associated with the addition of 70 kg.fed^{-1} potassium humate followed by 500 kg.fed^{-1} potassium silicate, while highest value of Si was associated with addition of 500 kg.fed^{-1} potassium silicate under irrigation regime at 80% from IWR. The same trend was true during both seasons. Similar positive results of the interaction between irrigation regimes and soil amendments on chemical constituents are in accordance with those obtained by El-Saady (2017); Kotb *et al.* (2018); Kotb (2019); Mahmoud *et al.* (2019) and Abd Allah *et al. (*2021).

Table 11. Interaction effect between irrigation system and soil amendments on chemical constituents of pepper plants during 2017 and 2018 seasons.

Treatments		N%		P%		K%		Si %		Total Chlorophyll mg g^{-1} FW	
		2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Surface irrigation	0	2.45i	2.84h	0.367i	0.393j	2.79i	3.08i	0.20g	0.24g	1.186i	1.205
	K Si 250	2.63h	2.99g	0.412g	0.432h	2.99h	3.24h	0.30cd	0.39e	1.233h	1.255
	K Si 500	2.78f	3.13e	0.441d	0.463e	3.14f	3.35f	0.32bc	0.42cd	1.264f	1.288
	K H35	2.71g	3.05f	0.429e	0.449g	3.06g	3.32g	0.23f	0.30g	1.248g	1.272
	K H70	2.85e	3.19d	0.459b	0.479c	3.21d	3.41e	0.25ef	0.33f	1.282e	1.305
Drip irrigation	0	2.70g	3.01g	0.379h	0.414i	3.00h	3.33fg	0.23f	0.34f	1.267f	1.312
	K Si 250	2.89d	3.19d	0.422f	0.457f	3.18e	3.52d	0.32b	0.50b	1.317d	1.369
	K Si 500	3.05b	3.32b	0.457c	0.490b	3.33b	3.67b	0.34a	0.53a	1.355b	1.401
	K H35	2.98c	3.27c	0.440d	0.475d	3.26c	3.60c	0.26e	0.40de	1.333c	1.379
	K H70	3.13a	3.39a	0.473a	0.507a	3.39a	3.74a	0.29d	0.43c	1.373a	1.421

Means followed by the same letter within each column do not significantly differed using Duncan's Multiple Rang Test at the level of 5%.

Irrigation system, irrigation regimes and soil amendments

It is obvious from Table (13) that the effect of triple interaction among irrigation system, irrigation regimes and soil amendments significantly affected the chemical constituents of sweet pepper plants. The highest mean values of chlorophyll content, N, P and K% in plants resulted from drip irrigation system at 80% of IWR with soil amendments of 70 kg.fed^{-1} potassium humate followed by 500 kg.fed^{-1} potassium silicate. While increase in Si concentration up to the highest value was recorded with the same treatments but with the addition of 500 kg.fed^{-1} potassium silicate under drip irrigation system. The same trend was true during both seasons. These results may be attributed to the effective roles of soil amendments as potassium humate or potassium silicate with drip irrigation system at 80 % IWR.–This treatment increased water uptake and improved essential elements absorption and availing them in the different plant physiological and biochemical processes and consequently improved chemical constituents' traits. Also, the availability of minerals in the soil solution due to the utilization of potassium humate or silicate, which enhanced their uptake by roots. These results are in agreement with those showed by Marodin *et al.* (2014) and Abdelaal *et al.* (2020).

Table 12. Interaction effect between irrigation regimes and soil amendments on chemical constituents of pepper plants during 2017 and 2018 seasons.

Treatments		N%		P%		K%		Si %		Total Chlorophyll mg g^{-1} FW	
		2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
80%	0	2.75i	3.08i	0.412i	0.441i	3.08i	3.37i	0.26gh	0.37g	1.275i	1.306
	K Si 250	3.08d	3.40d	0.495d	0.519d	3.42d	3.68d	0.38b	0.55b	1.357d	1.393
	K Si 500	3.25b	3.53b	0.526b	0.549b	3.57b	3.82b	0.40a	0.58a	1.389b	1.426
	K H35	3.18c	3.46c	0.513c	0.536c	3.49c	3.77c	0.31de	0.44de	1.372c	1.407
	K H70	3.32a	3.59a	0.544a	0.566a	3.64a	3.88a	0.32cd	0.47d	1.407a	1.441
60%	0	2.69j	3.00j	0.395j	0.425j	3.00j	3.30j	0.25h	0.33h	1.256j	1.293
	K Si 250	2.81h	3.14h	0.429h	0.456h	3.16h	3.43h	0.35c	0.50c	1.295h	1.342
	K Si 500	2.96f	3.28f	0.462f	0.489f	3.30f	3.55f	0.37b	0.53bc	1.325f	1.357
	K H35	2.88g	3.22g	0.445g	0.472g	3.23g	3.49g	0.27fg	0.40fg	1.307g	1.342
	K H70	3.03e	3.33e	0.479e	0.505e	3.35e	3.61e	0.30ef	0.42ef	1.341e	1.381
40%	0	2.28o	2.69o	0.311o	0.345o	2.60o	2.94o	0.14k	0.18l	1.147o	1.177
	K Si 250	2.39n	2.73n	0.327n	0.360n	2.69n	3.02n	0.21i	0.29i	1.173n	1.202
	K Si 500	2.55l	2.86l	0.359l	0.393l	2.85l	3.17l	0.22i	0.31hi	1.215l	1.251
	K H35	2.47m	2.80m	0.345m	0.378m	2.77m	3.11m	0.17j	0.21k	1.193m	1.229
	K H70	2.62k	2.94k	0.377k	0.408k	2.93k	3.23k	0.19j	0.26j	1.236k	1.268

Means followed by the same letter within each column do not significantly differed using Duncan's Multiple Rang Test at the level of 5%.

Table 13. Interaction effect among irrigation system, regime and soil amendments on chemical constituents of pepper plants during 2017 and 2018 seasons.

Treatments			N%		P%		K%		Si %		Total Chlorophyll mg g^{-1} FW	
			2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Surface irrigation	80%	0	2.62lm	2.99op	0.406q	0.431o	2.97t	3.24m	0.25jk	0.32n	1.236p	1.253p
		K Si 250	2.93h	3.29gh	0.488g	0.504g	3.34j	3.51i	0.37b-d	0.50e-g	1.312jk	1.339kl
		K Si 500	3.11e	3.42e	0.518d	0.532e	3.49f	3.64g	0.39ab	0.53de	1.339g-i	1.368hi
		K H 35	3.05fg	3.33fg	0.506e	0.521f	3.40h	3.58h	0.30f-h	0.39kl	1.325ij	1.351i-k
		K H 70	3.18d	3.47cd	0.536b	0.547d	3.56d	3.69f	0.31e-g	0.42jk	1.354fg	1.380gh
	60%	0	2.56no	2.92qr	0.389t	0.414p	2.89v	3.17n	0.23kl	0.28op	1.218q	1.243pq
		K Si 250	2.69jk	3.04mn	0.424o	0.444n	3.06r	3.29l	0.34de	0.45h-j	1.255o	1.279o
		K Si 500	2.82i	3.18jk	0.454k	0.475i	3.20n	3.38k	0.37b-d	0.48f-i	1.282mn	1.303n
		K H 35	2.74j	3.11l	0.440m	0.460l	3.13p	3.34k	0.25jk	0.34mn	1.267no	1.291no
		K H 70	2.88i	3.23ij	0.473i	0.493h	3.26l	3.45j	0.27h-j	0.36lm	1.298kl	1.323lm
	40%	0	2.18t	2.61w	0.305z	0.335w	2.50z	2.84r	0.11p	0.13t	1.103v	1.119v
		K Si 250	2.28s	2.65w	0.324y	0.349v	2.58z	2.93q	0.19mn	0.23qr	1.131u	1.148u
		K Si 500	2.42q	2.78u	0.351v	0.383s	2.74x	3.04p	0.20l-n	0.25pq	1.172s	1.194s
		K H 35	2.35r	2.71v	0.340w	0.367t	2.65y	3.00p	0.14op	0.16st	1.151t	1.175t
		K H 70	2.49p	2.85st	0.370u	0.399q	2.81w	3.11o	0.16no	0.20rs	1.194r	1.213r
Drip irrigation	80%	0	2.87i	3.17k	0.418p	0.451m	3.18o	3.50i	0.27h-j	0.42jk	1.315j	1.358ij
		K Si 250	3.23d	3.51c	0.502f	0.533e	3.50e	3.86d	0.38a-c	0.60ab	1.401d	1.447cd
		K Si 500	3.38b	3.64b	0.534b	0.567b	3.64b	4.01b	0.41a	0.64a	1.439b	1.484b
		K H 35	3.31c	3.59b	0.521c	0.552c	3.58c	3.95c	0.31e-g	0.49e-h	1.419c	1.463c
		K H 70	3.46a	3.71a	0.551a	0.586a	3.71a	4.07a	0.34d-f	0.52e-f	1.459a	1.502a
	60%	0	2.83i	3.07lm	0.402r	0.436o	3.11q	3.44j	0.26i-k	0.39kl	1.294lm	1.342jk
		K Si 250	2.93h	3.24hi	0.433n	0.467k	3.25m	3.58h	0.35cd	0.55cd	1.335hi	1.404ef
		K Si 500	3.10ef	3.38ef	0.469j	0.503g	3.40i	3.72f	0.38bc	0.58bc	1.367f	1.411e
		K H 35	3.02g	3.32g	0.450l	0.485i	3.33k	3.63g	0.29g-i	0.45ij	1.346gh	1.394fg
		K H 70	3.18d	3.42e	0.485h	0.518f	3.43g	3.78e	0.32e-g	0.47g-i	1.384e	1.438d
	40%	0	2.39qr	2.77u	0.316z	0.355u	2.70x	3.05p	0.16no	0.22qr	1.191r	1.236q
		K Si 250	2.51op	2.81tu	0.331x	0.371t	2.80w	3.12o	0.23kl	0.34mn	1.215q	1.256p
		K Si 500	2.67kl	2.95pq	0.368u	0.402q	2.95u	3.29l	0.24jk	0.37lm	1.258o	1.307mn
		K H 35	2.59mn	2.88rs	0.350v	0.389r	2.88v	3.20mn	0.19mn	0.26pq	1.234p	1.282o
		K H 70	2.74j	3.02no	0.384t	0.417p	3.04s	3.37k	0.21lm	0.31no	1.277n	1.323lm

Means followed by the same letter within each column do not significantly differed using Duncan's Multiple Rang Test at the level of 5%.

CONCLUSION

Finally, it could be recommended that the drip irrigation system at 80% following irrigation at 60% of IWR with soil amendments at 70 kg/fed. from potassium humate followed with 500 kg/fed. from potassium silicate, to obtain the highest vegetative growth and the best chemical constituents traits of sweet pepper plants under the conditions similar to this study.

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تأثير بعض محسنات التربة على المحصول الثمري والبذري للفلفل الحلو تحت ظروف الإجهاد المائي:
أـ الصفات الخضرية والمكونات الكيميائية

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الملخص

أجريت هذه الدراسة بمزرعة خاصة بمحافظة الدقهلية بمصر ، لبحث استجابة نبات الفلفل الحلو صنف كاليفورنيا وندر لنقص مياه الري تحت نظامي الري السطحى والري بالتنقيط مع اضافات محسنات التربة ، على النموالخضرى والمكونات الكيميائية. وكانت عدد معاملت التجربة 30 معاملة مرتبة في تصميم شرائح متعامدة. تم تخصيص الشرائح الأفقية لأنظمة الري (الري السطحي والري بالتنقيط) ، بينما خصصت الشرائح الرأسية لمستويات الري 40 % و 60 % و 80 % من الاحتياجات المائية، بينما تضمنت القطع الفرعية خمسة معاملات أضافات للتربة. وهى (بدون اضافات، 250 كجم ، 500 كجم خام سيليكات البوتاسيوم للفدان، كجم35 و 70 كجم هيومات بوتاسيوم للفدان). أشارت نتائج كلا الموسمين إلى أن نظام الري بالتنقيط أنتج قيم أعلى معنويا للصفات الخضرية والكيميائية مقارنة بنظام الري السطحي. وكانت أفضل النتائج لصفات النمو الخضري والمحتوى الكيميائي للأوراق عند رى النباتات بمعدل 80٪ ويليه الرى عند مستوى 60% من الاحتياجات المائية. كما أوضحت النتائج أنه تم الحصول على أعلى متوسط قيم للصفات الخضرية والكيميائية من اضافة محسنات التربة عند 70 كجم / فدان من هيومات البوتاسيوم تليها 500 كجم / فدان من سيليكات البوتاسيوم. بالإضافة إلى ذلك أشارت النتائج إلى أنه تم الحصول على القيم المتوسطة الأعلى للصفات الخضرية والكيميائية اضافة محسنات التربة عند 70 كجم / فدان من هيومات البوتاسيوم بعد 500 كجم / فدان من سيليكات البوتاسيوم تحت نظام الري بالتنقيط عند 80٪ ويليه الري عند مستوى 60٪ من الاحتياجات المائية. لذلك نوصي بهذ المعاملة لأنها توفر كمية مياه الري وتعطى أفضل الصفات الخضرية والكيميائية لنبات الفلفل الحلو في ظل ظروف هذه الدراسة.